Rational Formula ESCH V-3

$$Q = C \times i \times A$$

Where:
Q(cubic feet/second), Peak Rate of Runoff, is calculated from above equation.

C, Runoff Coefficient, is found from (ESCH V-29, Table 5-2)

T(minutes), Time of Concentration, is calculated for:
overland flow (ESCH V-11, Plate 5-1)
shallow concentrated (ESCH V-12, Plate 5-2)
channel flow (ESCH V-13, Plate 5-3)

i, (inches/hour), Average Rainfall Intensity, from (ESCH V-14 to V-280

A (acres), Drainage Area, determined from USGS maps or topographic survey

1. **For a Lynchburg commercial development of 25 acres, with 250,000 square feet of roof top, with 10 acres of asphalt paving for streets and parking, 4 acres of woodlands, and with the remainder in lawn on heavy soils with slopes greater than 7%, what is the weighted average runoff coefficient based upon the highest values of individual runoff coefficients?**

Convert roof top area from square feet to acres (1 acre = 43,560 square feet):

A (Area of roof top, acre) = square feet of roof top / 43,560 (square feet)

A (acres) = ( ) square feet / 43,560 square feet = ( ) acres

From ESCH V-29, Table 5-2:

Land use:	Runoff Coefficient x Area(acres) = C x A
Roof	( ) x ( ) = ( )
Asphalt Paving	( ) x ( ) = ( )
Woodlands	( ) x ( ) = ( )
Lawn	( ) x ( ) = ( )
	Total C x A = ( )

C, Weighted Average Runoff Coefficient = Total C x A / Total A(acres) = ( )

2. Given a total time of concentration of 20 minutes for the same development, what is the peak rate of runoff from a 10-year storm?

From ESCH V-14:

Locate Time of Concentration, T(minutes) = ( )minutes on horizontal axis.

Locate curve for given storm frequency = ( )year.

From horizontal axis, read up to curve for given storm frequency, and read to left to vertical axis for rainfall intensity:

Rainfall intensity, i (in/hr) = ( )in/hr.

Weighted average runoff coefficient, calculated from previous problem, C = ( ).

$$Q = C \times i \times A$$

Q (Peak rate of runoff, cfs) = ( ) x ( ) x ( ) = ( )cfs

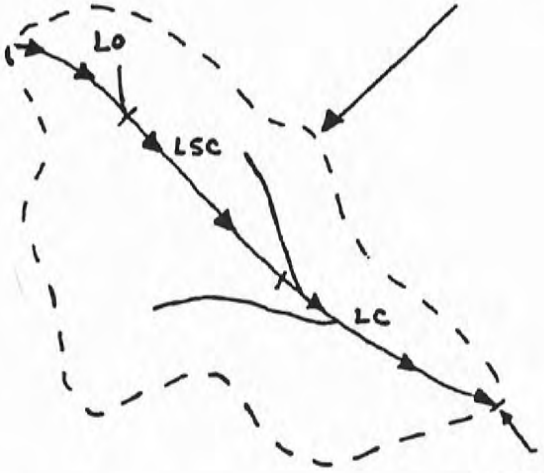
Example 5-1

A project is to be built in southwest Campbell County, Virginia. The following information was determined from field measurement and/or proposed design data:

Drainage Area: 80 acres

30% - Rooftops (24 acres)
10% - Streets and driveways (8 acres)
20% - Average lawns @ 5% slope on sandy soil (16 acres)
40% - Woodland (32 acres)

Watershed = 80 acres at the design point



Design Point

L_o = 200 ft. (4% slope or 0.04 ft./ft.); average grass lawn.

L_{sc} = 1000 ft. (4% slope or 0.04 ft./ft.); paved ditch.

L_c = 2000 ft. (1% slope or 0.01 ft./ft.); stream channel.

Find: Peak runoff rate from the 2-year frequency storm.

Solution:

1. Drainage Area (A) = 80 acres (given).

2. Determine runoff coefficient (C):

Calculate Weighted Average

	Area	x	C (Table 5-2)		
Rooftops	24	x	0.9	=	21.6
Streets	8	x	0.9	=	7.2
Lawns	16	x	0.15	=	2.4
Woodland	32	x	0.10	=	3.2
	80				34.4

$$C = \frac{34.4}{80} = 0.43$$

3. Determine the Time of Concentration (T_c) to the Design Point:

A. Overland flow (L_o)

Using Plate 5-1, T_t = 15 minutes

B. Shallow concentrated flow (L_{sc})

Using Plate 5-2 and the equation, $T_t = \frac{L}{60V}$

1000 ft. length, paved ditch, 4% slope (.04 ft./ft.);
V = 4 fps (from Plate 5-2)

$L_{sc} = \frac{1100}{60(4)} = 4.2$ minutes

C. Channel Flow (L_c)

Using Plate 5-3:

2000 ft. length and 1% slope (.01 ft./ft.)

(2000) (.01) = 20 ft. height of most remote point of channel above outlet.

L_c = 16 minutes.

4. Add all the travel times to get T_c.

15 + 4.2 + 16 = 35.2

T_c = 35.2 minutes.

5. Determine the Rainfall Intensity value (i) for the 2-year design storm (using Plate 5-4, Lynchburg Chart).

   (i) = 2.1 inches per hour.

6. Determine the peak discharge Q in cfs.

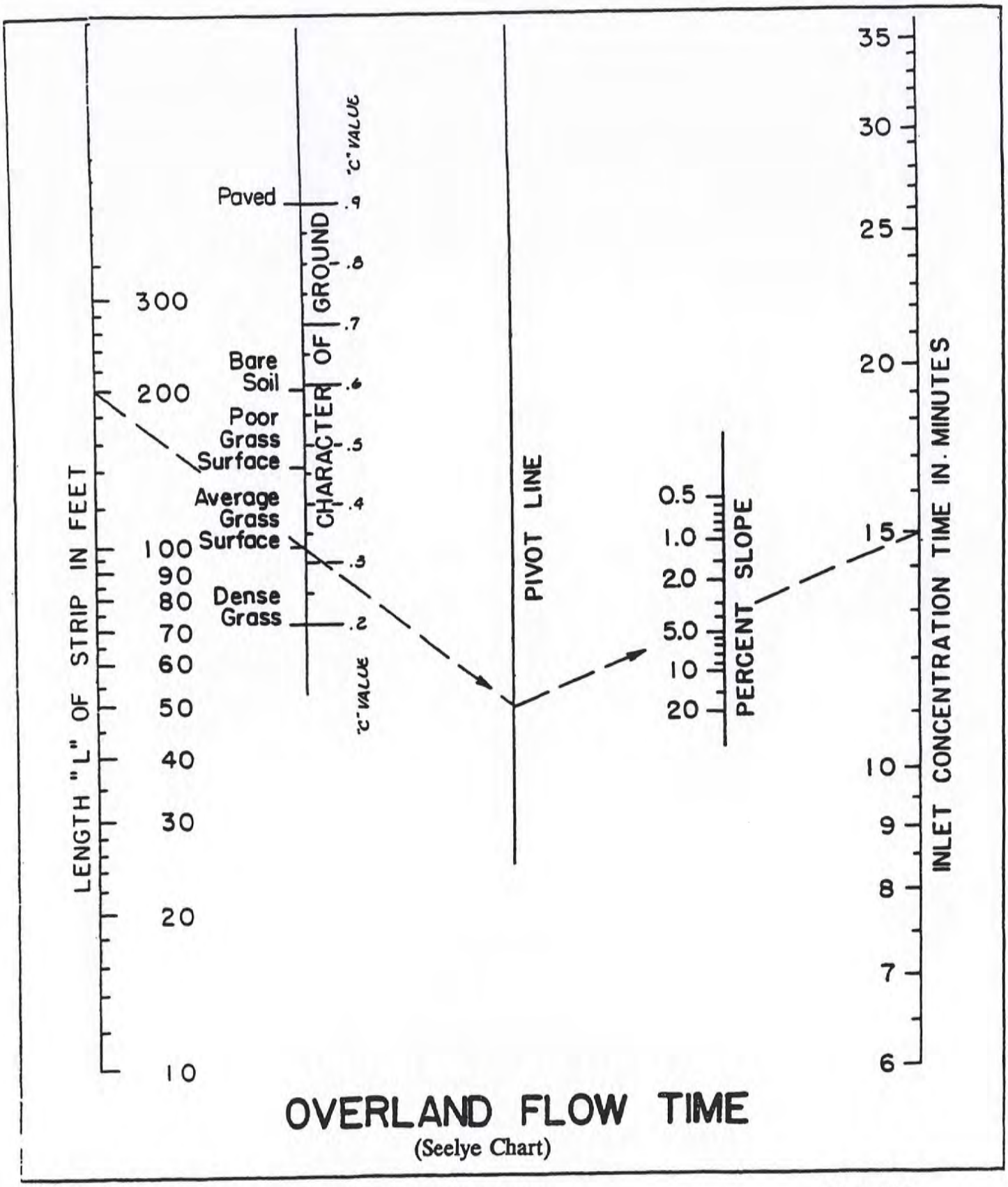
   Q = (C) (i) (A)
   = (.43)(2.1)(80)
   = 72.2 cfs

TABLE 5-2
VALUES OF RUNOFF COEFFICIENT (C) FOR RATIONAL FORMULA

Land Use	C	Land Use	C
Business:		Lawns:	
Downtown areas	0.70-0.95	Sandy soil, flat, 2%	0.05-0.10
Neighborhood areas	0.50-0.70	Sandy soil, average, 2-7%	0.10-0.15
		Sandy soil, steep, 7%	0.15-0.20
		Heavy soil, flat, 2%	0.13-0.17
		Heavy soil, average, 2-7%	0.18-0.22
		Heavy soil, steep, 7%	0.25-0.35
Residential:		Agricultural land:	
Single-family areas	0.30-0.50	Bare packed soil	
Multi units, detached	0.40-0.60	* Smooth	0.30-0.60
Multi units, attached	0.60-0.75	* Rough	0.20-0.50
Suburban	0.25-0.40	Cultivated rows	
		* Heavy soil, no crop	0.30-0.60
		* Heavy soil, with crop	0.20-0.50
		* Sandy soil, no crop	0.20-0.40
		* Sandy soil, with crop	0.10-0.25
		Pasture	
		* Heavy soil	0.15-0.45
		* Sandy soil	0.05-0.25
		Woodlands	0.05-0.25
Industrial:		Streets:	
Light areas	0.50-0.80	Asphaltic	0.70-0.95
Heavy areas	0.60-0.90	Concrete	0.80-0.95
		Brick	0.70-0.85
Parks, cemeteries	0.10-0.25	Unimproved areas	0.10-0.30
Playgrounds	0.20-0.35	Drives and walks	0.75-0.85
Railroad yard areas	0.20-0.40	Roofs	0.75-0.95

Note: The designer must use judgement to select the appropriate "C" value within the range. Generally, larger areas with permeable soils, flat slopes and dense vegetation should have the lowest C values. Smaller areas with dense soils, moderate to steep slopes, and sparse vegetation should be assigned the highest C values.

Source: American Society of Civil Engineers



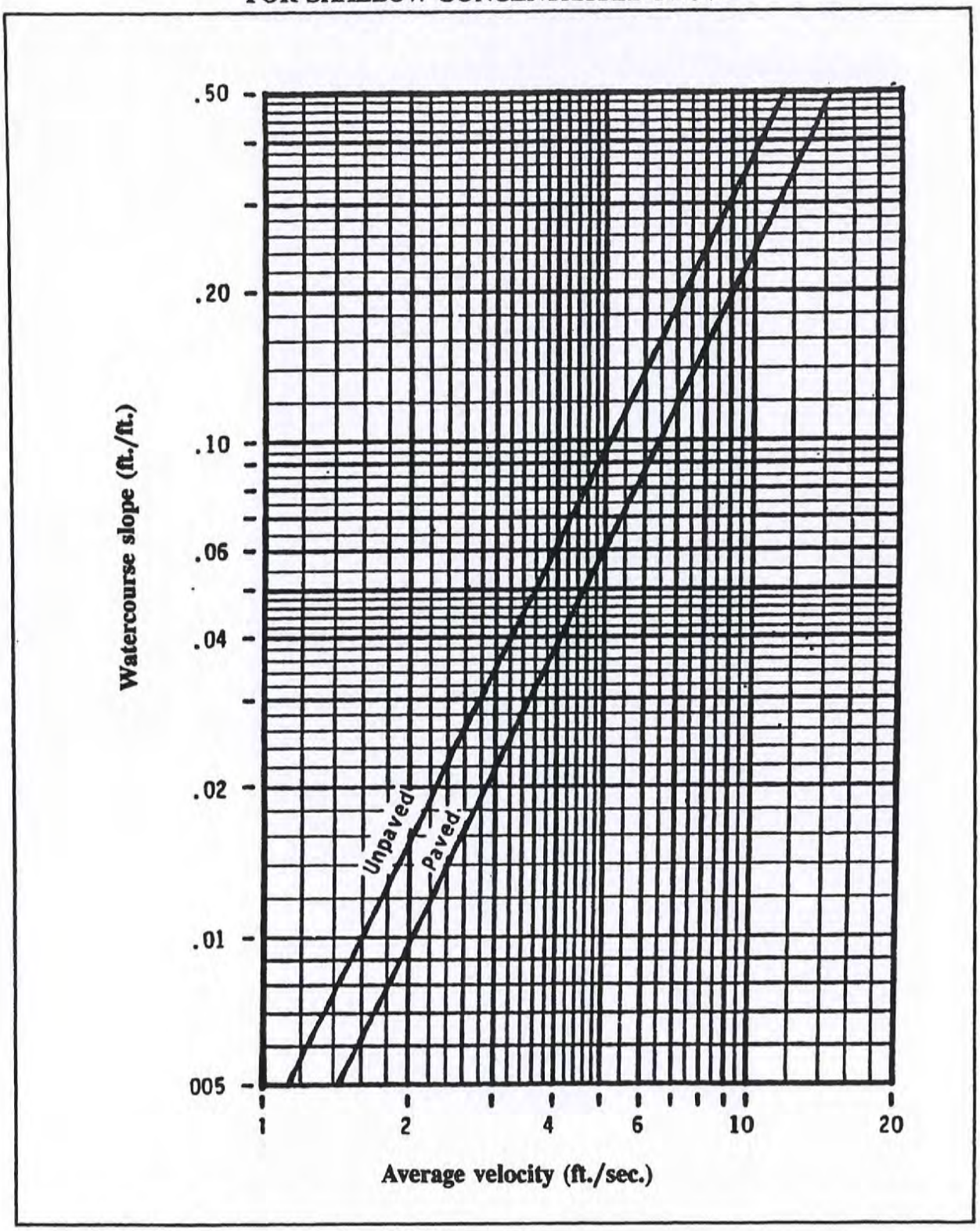
OVERLAND FLOW TIME

(Seelye Chart)

Source: Data Book for Civil Engineers, E.E. Seelye

Plate 5-1

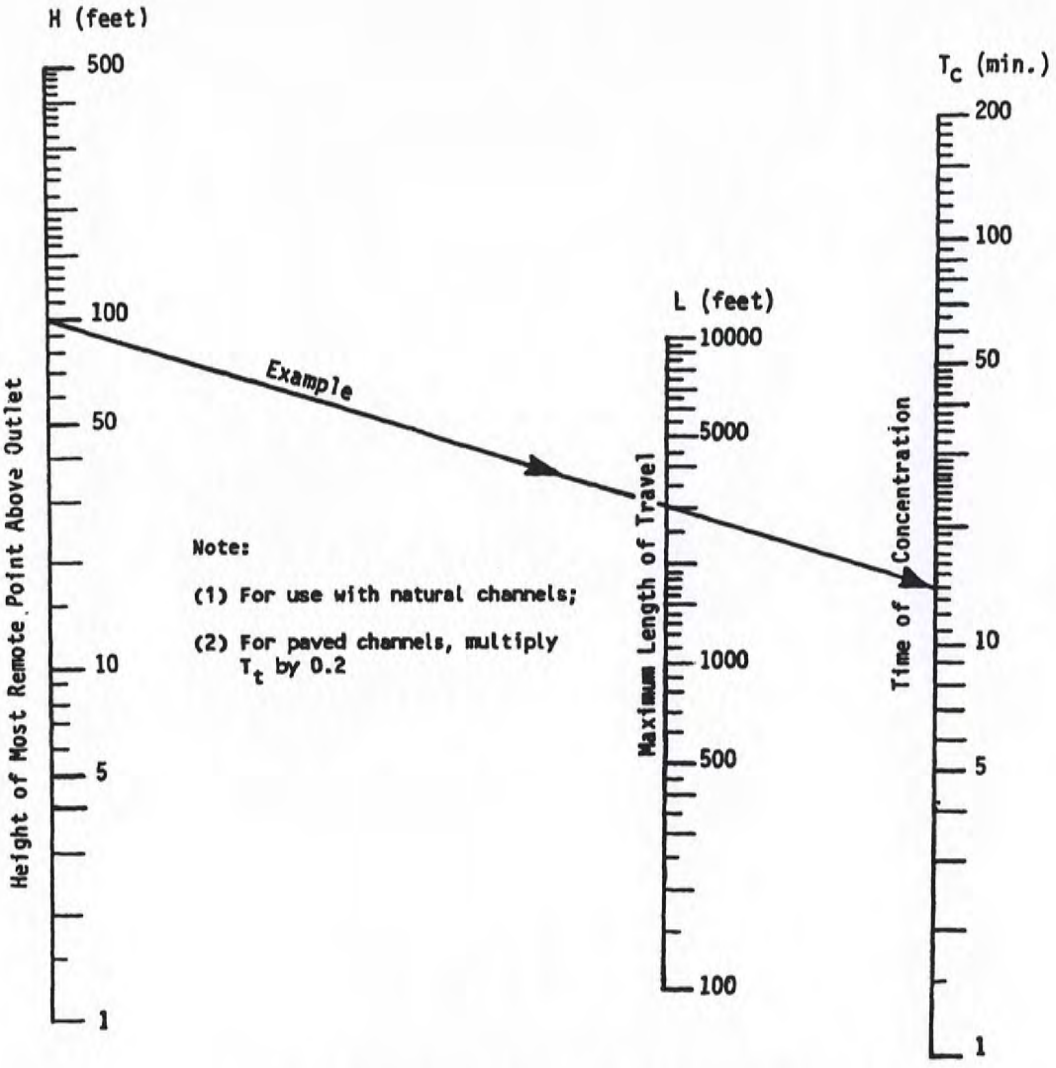
AVERAGE VELOCITIES FOR ESTIMATING TRAVEL TIME FOR SHALLOW CONCENTRATED FLOW



Source: USDA-SCS

Plate 5-2

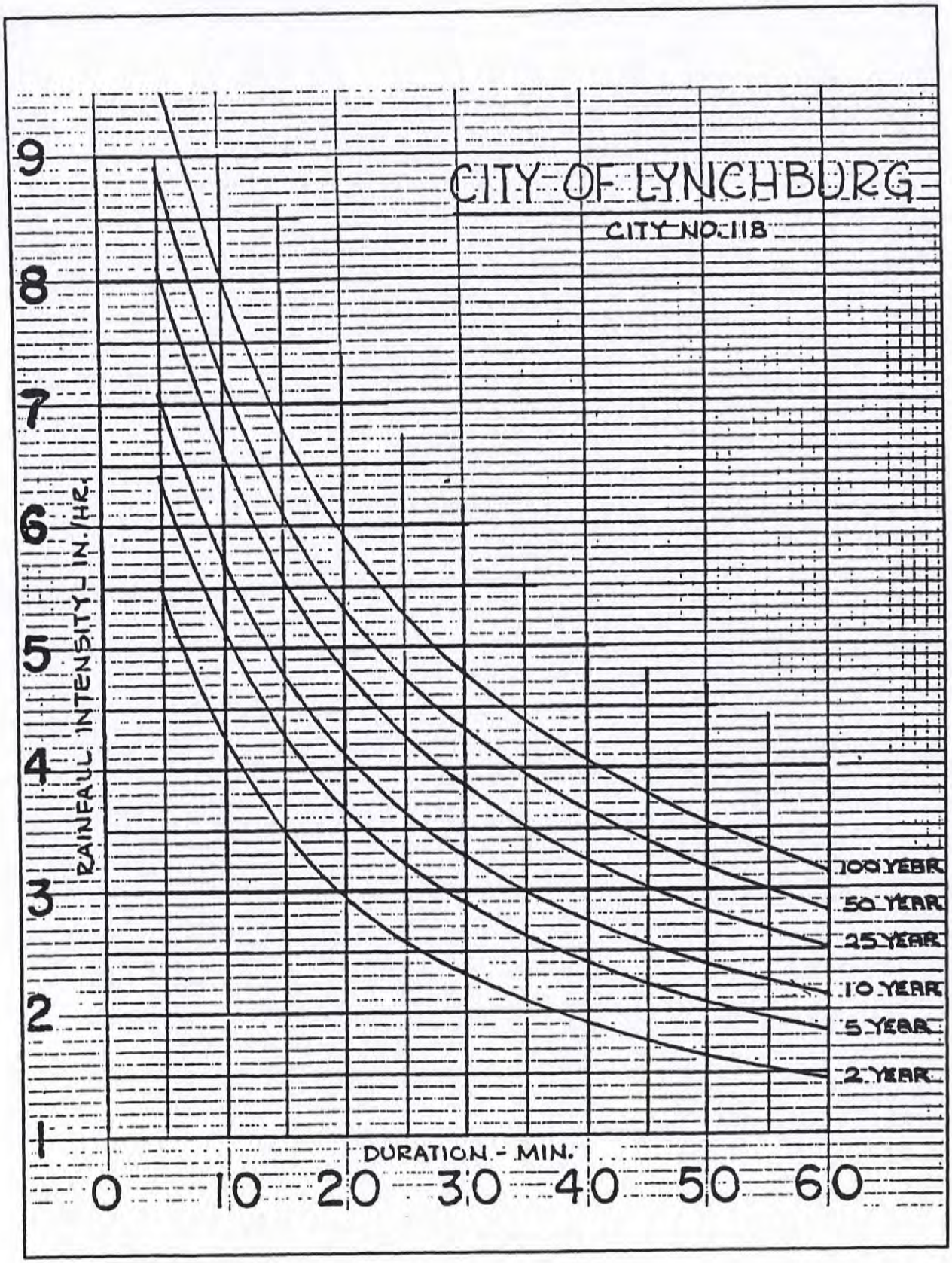
TRAVEL TIME FOR CHANNEL FLOW
(Kirpich Chart)



TIME OF CONCENTRATION OF SMALL DRAINAGE BASINS

Source: VDOT

Plate 5-3



Source: VDOT

Plate 5-4